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USAARL REPORT NO. 70-5

# MEASUREMENT OF TOXIC HAZARD DUE TO FIRING THE WEAPONS OF THE UH-1B ARMED HELICOPTER

By

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August 1969

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY
Fort Rucker, Alabama

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## FOREWORD

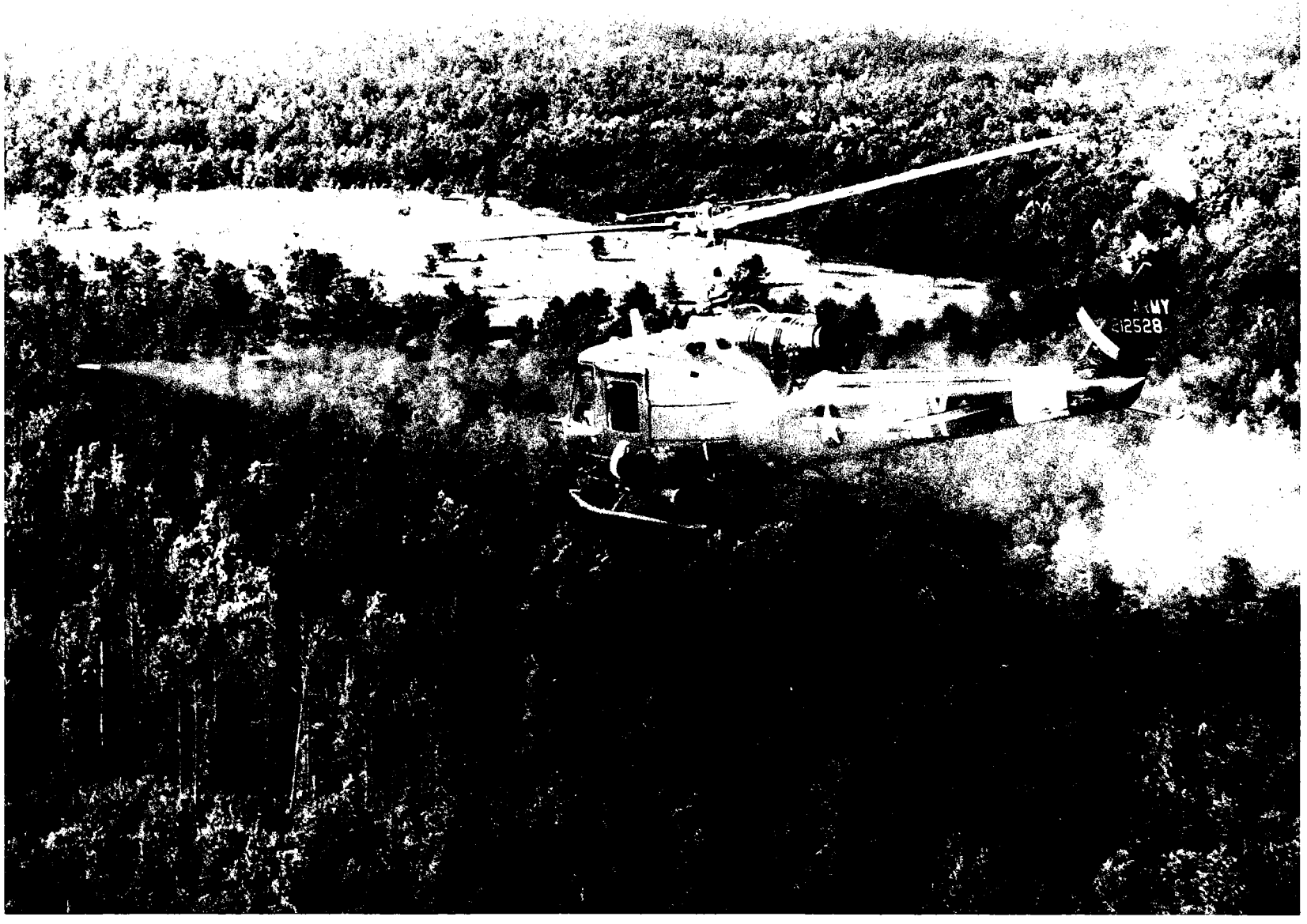
This study is a continuation of work initiated by LTC W. Schane and CPT G. Hody at the U. S. Army Aeromedical Research Unit. The report was written at Geoscience Limited, 410 S. Cedros, Solana Beach, California 92075, under U. S. Army Contract No. DABCO1-69-C-0247.

ABSTRACT

The toxic exhaust products of machine guns and rockets fired from armed helicopters can create a hazard for the crew. A toxic hazard evaluation was carried out with the UH-1B armed helicopter. Special methods were used to measure rapidly changing levels of carbon monoxide in the helicopter during actual flight testing. The exposure to metallic particles was also recorded. No toxic levels of weapons exhaust were present in the cabin during any practical mission profile with the specific weapons tested. These tests are part of a continuing armed helicopter toxic hazard study program at USAARL.

APPROVED: Robert W. Bailey

ROBERT W. BAILEY
COL, MSC
Commanding




THE UH-1B ARMED HELICOPTER

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# MEASUREMENT OF TOXIC HAZARD DUE TO FIRING THE WEAPONS OF THE UH-1B ARMED HELICOPTER

## INTRODUCTION

The exhaust products of weapons can collect in armed helicopter cabins during rapid or prolonged firing. Exposure of the crew to these highly toxic gases and aerosols is usually very brief but it may be intense. The long term effects on health are rarely of concern because the total dose of inhaled toxic material is small. It is very important, however, to be sure that aircrew performance is not impaired, even briefly. Eye irritation, nausea, and elevated blood carbon monoxide levels have resulted from excessive exposure to exhaust products of weapons [1,10,11]. The risk of combat missions can be severely increased by these factors; thus, the probability of their occurrence must be investigated.

Evaluation of the toxic hazard can be made from a chemical description of the contaminants present in the exhaust, their concentration, and the duration of exposure. The gases, vapors, and aerosol components of the exhaust from typical Army weapons have been described[2]. However, analysis of such a complex mixture is not presently possible in the aircraft environment. The toxic hazard can be evaluated, however, by a continuous measurement of carbon monoxide concentrations present in the cabin during the flight. The development of the measurement method and the required instrumentation has been discussed in previous reports[3,4]. The results reported here were obtained in tests performed at Ft. Rucker in 1967. A brief partial report was made at that time[5]. Complete data reduction and documentation has since been performed.

## MATERIALS AND METHODS

### Continuous Quantitative CO Measurement

A continuous record of the carbon monoxide concentration in the aircraft was obtained with an instrument constructed at USAARL. This carbon monoxide recorder was built by extensive modification of an industrial detector. The changes which were made improved the response time and provided precise reaction chamber temperature control. A self-contained aircraft power supply adapter, air sample pump, and strip chart recorder (2" paper width) were included in the modified unit. The instrument detected carbon monoxide by the heat which was produced when the gas was oxidized over a heated catalyst. The modifications have not been described as yet in the literature but the general approach was documented in a previous report[4].

### Qualitative CO Measurement

Carbon monoxide exposures were also estimated with NBS-type indicator tubes[6]. These tubes require a very stable rate of sample air flow. Consequently, air was drawn through the tubes with an electric pump and the rate of flow was continuously metered. A flow rate of 90 ml/minute was used.

### Calibration

The CO recorder was calibrated with premixed as well as dynamically generated mixtures of carbon monoxide in air. Typical exposure times in the aircraft were so brief that even the fast responding CO meter did not have sufficient time to reach correct peak readings. Thus, it was necessary to adjust the magnitude of the recorded carbon monoxide levels for the effect of the short exposure times. This correction was obtained from calibration curves of the transient response

of the instrument (Figure 1). In all cases, the corrections were selected to reveal the highest CO level which might have been present. Each batch of the NBS-type indicator tubes used was calibrated with the same gas mixtures described above. The overall accuracy of the carbon monoxide measurement was within $\pm$ 20% at concentrations above 50 parts per million (PPM).

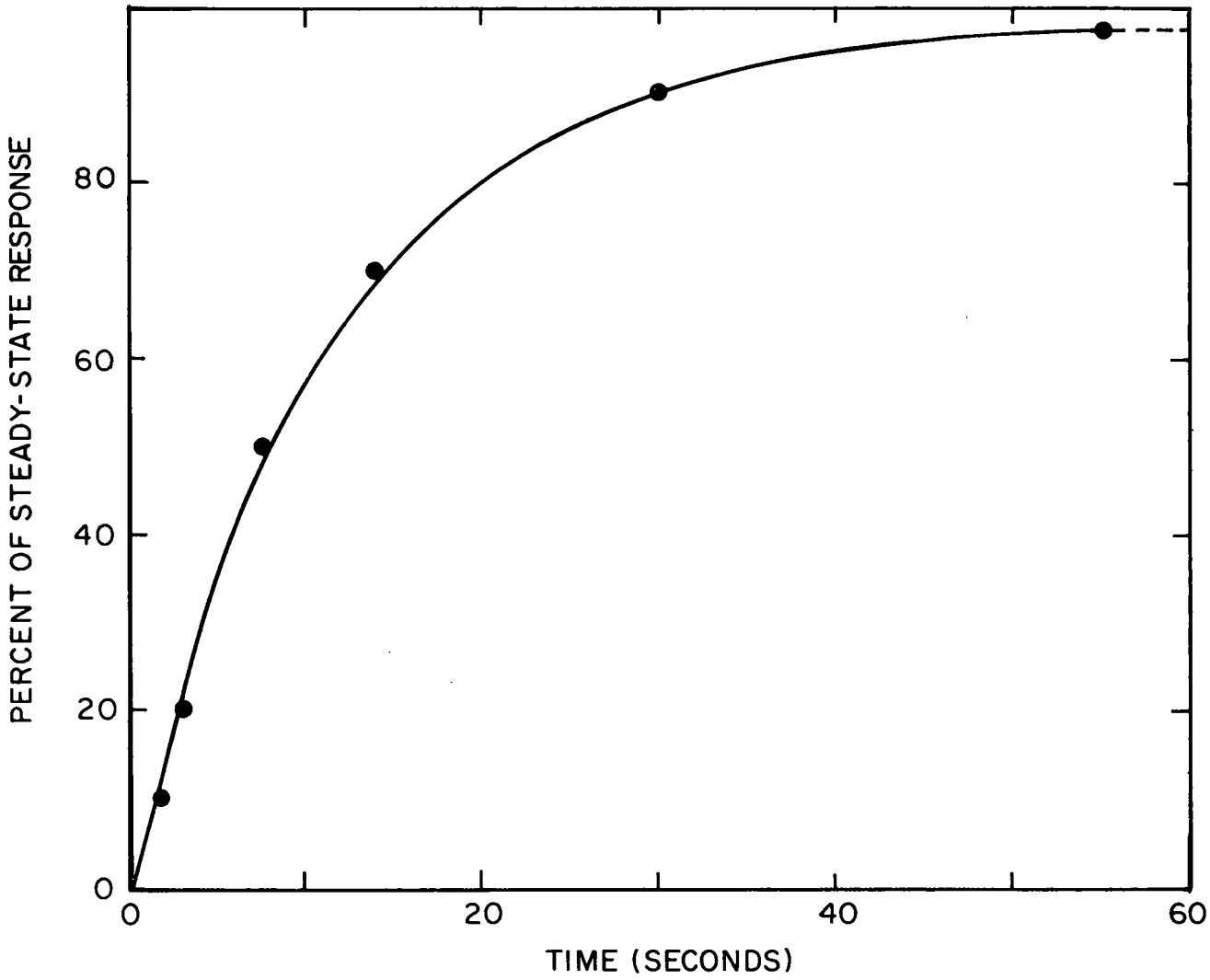


FIGURE 1. CARBON MONOXIDE DETECTOR TRANSIENT RESPONSE

### Particle Sampling and Analysis

The total quantity of metal particle aerosol which would have been inhaled during a typical busy one-day mission was also estimated. The particles were collected on a #41H Whatman Filter Disc with a small electric sampler which drew air at the rate of 3 liters per minute. The mineral content of the filters was analyzed at a private laboratory* by means of atomic emission spectroscopy.

### Probe Locations

The CO recorder sample intake probe was placed over the pilot's shoulder harness; the NBS tube sampler and particle sampler were clipped to the flight suit of a rear-seat occupant during the tests.

### Weapons Tested

Several thousand rounds each of M-60 and minigun ammunition, 10 rounds of S-11/M-22 wire-guided missile and 42 pairs of 2.75" FFAR rockets were fired. In the case of the carbon monoxide measurements, the results for each weapon and for a number of flight conditions will be given separately. In the case of the aerosol exposure the sum of all the particles collected during the tests will be reported.

## RESULTS

### Carbon Monoxide Measurements

The results of the carbon monoxide measurements for the machine guns and the S-11/M-22 wire-guided missile are grouped in summary form in Table 1. The maximum carbon monoxide concentrations reached are given in parts of carbon monoxide per million parts of air (PPM); the percentage composition is obtained by multiplying PPM by $10^{-4}$. The product

*Aerojet-General Corporation, Von Karman Center, Azusa, California 91702. Analysis by M. L. Moberg.

| WEAPON TESTED | FLIGHT CONDITION | DOOR CONDITION | MAXIMUM CO CONCENTRATION (PPM) | MAXIMUM EXPOSURE TIME (MIN.) | PRODUCT OF CONCENTRATION AND TIME (PPM MIN) |
|---|---|---|---|---|---|
| M-60 MACHINE GUN (QUAD) | HOVER | OPEN | < 50 | < 0.2 | < 10 |
| " | FORWARD FLIGHT | OPEN/CLOSED | NO DETECTABLE LEVELS | (LESS THAN 25 PPM AT ALL TIMES) | |
| MINIGUN (DUAL) | HOVER | OPEN | < 50 | < 0.2 | < 10 |
| " | FORWARD FLIGHT | OPEN/CLOSED | NO DETECTABLE LEVELS | (LESS THAN 25 PPM AT ALL TIMES) | |
| WIRE-GUIDED MISSILE | HOVER AND FORWARD FLIGHT | CLOSED | < 25 | < 0.2 | < 5 |

TABLE 1. CARBON MONOXIDE EXPOSURE DURING FIRING OF MACHINE GUNS AND WIRE-GUIDED MISSILES (MAXIMUM LEVELS MEASURED)

of the concentration and the duration of the exposure is also given. This product is a measure of the "dose" of carbon monoxide to which the air crew was exposed. In general, the measurements taken with the NBS indicator tubes paralleled those reported for the continuous recorder, and are not listed separately.

Exposures to carbon monoxide attributable to rocket firing with the 2.75" FFAR are listed in Table 2. The mean air concentration is an average of all results and is reported on the basis of the concentration

| | DOORS OPEN | DOORS CLOSED | UNITS |
|---|---|---|---|
| MEAN AIR CONCENTRATION | 25 | 50 | PPM/Pair |
| STANDARD DEVIATION OF ABOVE | 11 | 25 | PPM/Pair |
| MAXIMUM EXPOSURE TIME | 0.2 | 0.1 | Minutes |
| TYPICAL "DOSE" (Concentration-Time Product) | 5 | 5 | PPM Min/Pair |
| TYPICAL EXPOSURE AFTER FIRING SALVO OF 48 PAIR | 240 | 240 | PPM Min |
| 48 PAIR EXPOSURE ASSUMING WORST CONCENTRATION AND LONGEST EXPOSURE TIME | 5300 | 2600 | PPM Min |
| PERMISSIBLE EXPOSURE (If Received Within One Minute) | 8000 | | PPM Min |

TABLE 2. CARBON MONOXIDE EXPOSURE ASSOCIATED WITH FIRING OF THE 2.75" FFAR ROCKET

related to the firing of a single rocket pair (the actual firing sequence and raw data are contained in the appendix). The "typical dose" consists of the product of the mean air concentration and the maximum exposure time, again on a per pair basis. Estimates of the dose of carbon monoxide which would have been inhaled for a forty-eight pair rocket salvo were calculated from typical and maximum "per pair" data by multiplying the "per pair" figures by forty-eight. No actual large salvos were fired during the flight tests.

### Particle Analysis

The mineral content of the filter paper disc used to collect particles is listed in the appendix. The data are in total milligrams of minerals. These numbers can be converted to realistic dose estimates for human beings in the flight environment. The breathing rate of individuals in a stressful environment is highly variable but typical values of air flow range from 10 to 100 liters per minute[7]. The higher values are rarely sustained for long periods. A mean pulmonary air flow rate of 30 L/MIN was assumed. The majority of particles emitted from the weapons are in the size range retained efficiently by the lungs. Thus, the amount of mineral matter retained by the crew members was assumed to be the same as the amount of mineral matter on the filter paper corrected for the difference between the filter's sampling rate and the assumed breathing air flow rate (a factor of about 10). The corrected data are presented in Table 3.

## CONCLUSIONS

The harmful effects of carbon monoxide include impairment of psychomotor skills, vision, and judgment. The severity of the impairment depends mainly upon the concentration of the gas in the respired air, the duration of exposure and the physical activity of the individuals[8]. An element of chance also exists when exposures are intense but brief as they are in the helicopter. In such cases the actual amount of

carbon monoxide inhaled may depend upon the location of the subject's mouth and nose and the relationship of their respiratory rhythm to the exact time-concentration history of the carbon monoxide gas in their environment. For these exposures the best analysis is to examine the worst case.

It is important to establish the maximum exposure to carbon monoxide which will be permitted. Moderate performance impairment can be tolerated in many industrial situations but in aircraft these same effects may be lethal. Suitable limits for armed helicopters were calculated for the Army by the Advisory Center on Toxicology of the National Research Council[9]. The levels were chosen to protect against visual impairment which can occur with carboxy-hemoglobin blood levels in excess of 5%. The levels picked were 8000 PPM MIN if the dose is received in one minute, 10,000 PPM MIN for ten minute exposures and 6000 PPM MIN for 30 minute exposures.

The measured results must be compared to these permissible levels. In the case of the machine guns and the M-11/S-22 missile, exposures recorded were at least one hundred times less than those which were considered permissible. The same was true of the 2.75" FFAR when fired in single pairs and small salvos. The calculated results for a typical firing of 48 pairs of 2.75" FFAR were also well below the exposure limits (a factor of 20 or more less). If the extremely unlikely combination of the highest recorded concentration and longest time were considered, the results would still be acceptable though the dose would be only slightly below the maximum permissible level. In general, the firings in which the doors were open yielded higher concentrations for shorter times so that the doses remained the same. Should the doors be open, larger variations from test to test would be expected due to the influence of random changes in wind and direction of flight.

Of the mineral components detected on the particle filter all were normal components of dust except copper and lead. The copper was present only in trace quantities and constituted no hazard. The permissible dose for lead was calculated from the threshold limit value (TLV) of 0.2 $mg/m^3$ as follows. The TLV's are industrial standards which assume an eight hour daily exposure. During an eight hour day an individual breathing at an average rate of 20 liters per minute would inhale about 10,000 liters of air or 10 $m^3$. If this air contained the TLV of lead, 0.2 $mg/m^3$, a total of 2 mg would be inhaled, thus 2 mg per day can be considered an acceptable exposure to lead. In this study, lead exposures (Table 3) were not expected to exceed 0.03 mg. This value clearly provides a large safety margin.

| METAL | DOSE (mg/day) |
|---|---|
| LEAD | 0.03 |
| COPPER | 0.008 |
| MAGNESIUM | 0.02 |
| ALUMINUM | 0.02 |
| SILICON | 0.03 |
| A breathing rate of 30 liters per minute is assumed for the man. | |

TABLE 3. MINERAL AEROSOL INHALATION DURING VERY ACTIVE ONE DAY ARMED HELICOPTER MISSION

From the above discussion it is clear that the occurrence of a toxic hazard on the UH-1B armed helicopter during the firing of the M-60 quad machine gun, dual minigun, S-11/M-22 wire-guided missile, and 2.75" FFAR rockets is extremely unlikely. However, carbon monoxide and other toxic materials are present in small quantities when the weapons are fired. Crewmembers should avoid exposure to other sources of toxic materials, particularly carbon monoxide. The effects of smoking and those of oxygen deficiency (such as occur at altitude) would be additive to the effects of the carbon monoxide present during the firing of weapons. These remarks apply particularly to the 2.75" FFAR rocket fired in large salvos, in which case the safety margin present with the other weapons may be considerably reduced.

## REFERENCES


1. Hody, G. L., and W. P. Schane, "Preliminary Carbon Monoxide Measurements in Armed Helicopters," USAARU Report No. 66-1, March 1966.

2. Scharf, P. B., B. B. Goshgarian, H. M. Nelson, and G. L. Hody, "Measurement of Exhaust Composition of Selected Helicopter Armament (Project WEST)," USAARU Report No. 67-10 and AFRPL-TR-67-203, 1967.

3. Hody, G. L., "Approach to the Evaluation of Toxic Hazards From Weapons Exhaust in Armed Helicopters," USAARU Report No. 67-5, 1966.

4. Hody, G. L., and R. L. Keiser, "Evaluation of Two Vibration Insensitive Catalytic Detectors for Carbon Monoxide," USAARU Report No. 66-2, 1966.

5. Hody, G. L., and P. Swidzinski, "Informal Report of Rocket Firing Experiment in UH-1B," USAARU unpublished letter report, USAARU-EMB, dated 19 July 1967.

6. Shepherd, M., "Rapid Determination of Small Amounts of Carbon Monoxide: Preliminary Report on the NBS Calorimetric Indicating Gel." Analytical Chemistry, 19:77, 1947.

7. Webb, P. editor; Bioastronautics Data Book, Chapt. 15, pp 273-289, NASA Pub. #SP-3006, 1964.

8. Patty, F. A., Industrial Hygiene and Toxicology, New York, Interscience, 1958.

9. Wands, R. C., personal communication.

10. Hody, G. L., "Carbon Monoxide Measurement in the Armed Chinook (CH-47B)." USAARU Letter Report to the U. S. Army Aviation Test Board (unpublished), 11 February 1966.

11. Schane, W. P., "Weapons Exhaust Accumulation on the Tail Ramp of a VCH-47A During Firing of an XM-24 Machine Gun in Flight." USAARU Letter Report (unpublished), November 1966.

APPENDIX - RESULTS OF PARTICLE ANALYSIS

**AEROJET-GENERAL CORPORATION**

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**VON KARMAN CENTER**

31 July 1967

Subject: Analysis of Special Filter Sample

To: Commanding Officer
U.S. Army
Aeromedical Research Unit
Box 577
Fort Rucker, Alabama 36360

Attn: Capt. G. L. Hody
Toxicological Branch

The analytical results given below were obtained on the materials found on filter #USAARU 27-JE-67-01 (Whatman 41H filter paper used in an air sampler at a flow rate of 3 liters/min). For trace analysis studies, contaminant contributions from blank filter papers can be significant and these must be carefully determined so that appropriate corrections can be made to the total analytical data. A minimum of 4 blanks were analyzed prior to studying the sample and these results averaged for a blank determination.

The data are quantitative with an expected precision of ± 10% of the reported number.

| | Total Milligrams Per Filter |
|---|---|
| Si | 0.003 ± 0.0003 |
| Pb | 0.003 ± 0.0003 |
| Cu | 0.0008 ± 0.00008 |
| Mg | 0.002 ± 0.0002 |
| Al | 0.002 ± 0.0002 |

M. L. Moberg, Manager
Analytical Laboratories Department
Chemical Products Division
Von Karman Center

| # OF ROCKETS FIRED | EXPOSURE TIME (SEC) | CO CONC. (PPM) | "DOSE (CONC. TIME PRODUCT) (PPM SEC) | (PPM MIN) | (PPM MIN/PAIR) |
|---|---|---|---|---|---|
| Single rocket | 2 | ~ 30 | ~ 60 | ~ 1 | ~ 2 |
| 1 pair | 8 | 400 | 3200 | 54 | |
| 1 pair | 10 | 140 | 1400 | 23 | |
| 1 pair | 9 | 230 | 2100 | 35 | |
| 2 pair | 9 | 370 | 3300 | 55 | 23 |
| Single rocket | 7 | 90 | 630 | 10 | 20 |
| 1 pair | 9 | 230 | 2100 | 35 | |
| 1 pair | 8 | 181 | 1460 | 24 | |
| 2 pair | 10 | 185 | 1850 | 31 | 16 |
| 2 pair | 8 | 256 | 2050 | 34 | 17 |
| 1 pair | 7 | 200 | 1400 | 23 | |
| 1 pair | 6 | 350 | 2100 | 35 | |
| 1 pair | 6 | 120 | 720 | 12 | |
| 1 pair | 6 | 275 | 1650 | 28 | |
| 2 pair | 8 | 235 | 1900 | 32 | 16 |
| 4 pair | 8 | 510 | 4100 | 70 | 18 |

MEAN DOSE 25 PPM MIN/PAIR
STD DEVIATION ±10.7 PPM MIN/PAIR

APPENDIX - CARBON MONOXIDE LEVELS DURING 2.75" FFAR ROCKET FIRING (DOORS CLOSED)

| # OF ROCKETS FIRED | EXPOSURE TIME(SEC) | CO CONC. (PPM) | "DOSE" (CONC. TIME PRODUCT) (PPM SEC) | (PPM MIN) | (PPM MIN/PAIR) |
|---|---|---|---|---|---|
| 1 pair | 4 | 1700 | 6700 | 110 | |
| 1 pair | 3 | 1000 | 3000 | 50 | |
| 1 pair | 3 | 600 | 1800 | 30 | |
| 1 pair | 3 | 1500 | 4500 | 75 | |
| 1 pair | 4 | 770 | 3100 | 51 | |
| 1 pair | 3 | 500 | 1500 | 25 | |
| 1 pair | 3 | 375 | 1250 | 21 | |
| 1 pair | 4 | 600 | 2400 | 40 | |
| 1 pair | 4 | 580 | 2350 | 39 | |
| 1 pair | 3 | 580 | 1750 | 29 | |
| 4 pair salvo | 5 | 1410 | 7200 | 120 | 30 |
| 3 single | 5 | 470 | 2333 | 39 | |
| 1 pair | 6 | 650 | 3900 | 65 | |
| 1 pair | 4 | 770 | 3060 | 52 | |
| 1 pair | 5 | 630 | 3150 | 53 | |
| 1 pair | 3 | 1500 | 4500 | 75 | |
| 1 pair | 2 | 1800 | 3600 | 60 | |
| 1 rocket | 3 | 700 | 2100 | 35 | |

MEAN DOSE 50 PPM MIN/PAIR
STD DEVIATION ±23 PPM MIN/PAIR

APPENDIX - CARBON MONOXIDE LEVELS DURING 2.75" FFAR ROCKET FIRING (DOORS OPEN)

Unclassified

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13. ABSTRACT

The toxic exhaust products of machine guns and rockets fired from armed helicopters can create a hazard for the crew. A toxic hazard evaluation was carried out with the UH-1B armed helicopter. Special methods were used to measure rapidly changing levels of carbon monoxide in the helicopter during actual flight testing. The exposure to metallic particles was also recorded. No toxic levels of weapons exhaust were present in the cabin during any practical mission profile with the specific weapons tested. These tests are part of a continuing armed helicopter toxic hazard study program at USAARL.

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| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Aircraft | | | | | | |
| Atmosphere | | | | | | |
| Detecting | | | | | | |
| Carbon Monoxide | | | | | | |
| Toxic | | | | | | |
| Weapon System | | | | | | |
| Helicopter | | | | | | |

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